

WHAT IS CLAIMED IS:

1. A lead-free joining material, comprising:

(a) a core part including zinc and tin as major components and at least any one
5 of bismuth and germanium as an additive element; and

(b) a surface layer covering the core part and including the major components
and the additive element, the surface layer including;

(i) a solid-solution phase in which a concentration of the additive
element is higher than a concentration of the additive element in the
10 core part, and the concentration of the additive element in the
solid-solution phase is in a range of 0.6 to 4.0 % by weight; and

(ii) a needle crystal which is dispersed in the solid-solution phase and
includes the zinc as a main component.

15 2. The lead-free joining material according to claim 1,

wherein the concentration of the additive element in the core part is in a range
of 0.3 to 1.0 % by weight.

3. The lead-free joining material according to claim 1,

20 wherein the surface layer has a depth of at least 2 μ m from an outermost
surface.

4. The lead-free joining material according to claim 1,

25 wherein the lead-free joining material is a particle which is substantially
spherical.

5. The lead-free joining material according to claim 1,
wherein an average concentration of the additive element in the whole lead-free joining material is in a range of 0.6 to 1.0 % by weight.

5 6. A lead-free solder paste, comprising:

(A) a lead-free joining material, including:

(a) a core part including zinc and tin as major components and at least any one of bismuth and germanium as an additive element; and

10 (b) a surface layer covering the core part and including the major components and the additive element, the surface layer including;

(i) a solid-solution phase in which a concentration of the additive element is higher than a concentration of the additive element in the core part, and the concentration of the additive element in the solid-solution phase is in a range of 0.6 to 4.0 % by weight; and

15 (ii) a needle crystal which is dispersed in the solid-solution phase and includes the zinc as a main component; and

(B) a flux.

7. The lead-free solder paste according to claim 6,

20 wherein the concentration of the additive element in the core part is in a range of 0.3 to 1.0 % by weight.

8. The lead-free solder paste according to claim 6,

25 wherein the surface layer has a depth of at least 2 μ m from an outermost surface.

9. The lead-free solder paste according to claim 6,

wherein the lead-free joining material is a particle which is substantially spherical.

5 10. The lead-free solder paste according to claim 6,

wherein an average concentration of the additive element in the whole lead-free joining material is in a range of 0.6 to 1.0 % by weight .

11. A joining method using a lead-free joining material, comprising:

10 coating a solder paste to a connection, the solder paste being formed by blending the lead-free joining material and a flux, and reflowing the solder paste,

wherein the lead-free joining material includes:

15 (a) a core part including zinc and tin as major components and at least any one of bismuth and germanium as an additive element; and

(b) a surface layer covering the core part and including the major components and the additive element, the surface layer including;

20 (i) a solid-solution phase in which a concentration of the additive element is higher than a concentration of the additive element in the core part, and the concentration of the additive element in the solid-solution phase is in a range of 0.6 to 4.0 % by weight; and

(ii) a needle crystal which is dispersed in the solid-solution phase and includes the zinc as a main component.

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12. The joining method according to claim 11,

wherein the concentration of the additive element in the core part is in a range of 0.3 to 1.0 % by weight .

13. The joining method according to claim 11,

5 wherein the surface layer has a depth of at least 2 „m from an outermost surface.

14. The joining method according to claim 11,

10 wherein the lead-free joining material is a particle which is substantially spherical.

15. The joining method according to claim 11,

15 wherein an average concentration of the additive element in the whole lead-free joining material is in a range of 0.6 to 1.0 % by weight.

16. A joining method using a lead-free joining material, comprising:

placing the lead-free joining material on a connection pre-coated with a flux;
and

reflowing the flux and the lead-free joining material,

20 wherein the lead-free joining material includes:

(a) a core part including zinc and tin as major components and at least any one of bismuth and germanium as an additive element; and

(b) a surface layer covering the core part and including the major components and the additive element, the surface layer including;

25 (i) a solid-solution phase in which a concentration of the additive element is higher than a concentration of the

additive element in the core part, and the concentration of the additive element in the solid-solution phase is in a range of 0.6 to 4.0 % by weight; and

(ii) a needle crystal which is dispersed in the solid-solution phase and includes the zinc as a main component.

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17. The joining method according to claim 16,

wherein the concentration of the additive element in the core part is in a range of 0.3 to 1.0 % by weight .

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18. The joining method according to claim 16,

wherein the surface layer has a depth of at least 2 μ m from an outermost surface.

15 19. The joining method according to claim 16,

wherein the lead-free joining material is a particle which is substantially spherical.

20. The joining method according to claim 16,

20 wherein an average concentration of the additive element in the whole lead-free joining material is in a range of 0.6 to 1.0 % by weight .